Environmental crisis and scientific thinking: which science education for sustainability?

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Responses

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Abstract

Global environmental problems are on the rise and more than ever before they are presenting humanity with the challenge of dealing with increasing levels of complexity and ignorance with regard to their nature and manifestations. To deal with such issues, a change of both culture and epistemology is required. The framework of sustainability science calls for a dialogical approach to knowledge production, valuing epistemic and reflexive knowledge that is produced in the course of cooperative exchanges between disciplines, people and groups, each one bringing different sets of experiences, values and methodological frameworks. It is argued that this approach to knowledge production is ethically relevant – bringing forth the values of co-existence and legitimization of the other- and it is at the basis of peaceful and sustainable co-existence of humanity on the Earth. Hence dealing with complex problems such as climate change in education is no longer and simply a matter of content but it involves the redefinition of the process of 'knowing', which is both and at the same time cognitive and relational, emotional and ethical. In this view, learning in science will involve a multiplicity of knowledge competences – linguistic, social, logical, practical and creative – to value mutual and collective engagements with personal actions in a global context.

Introduction

Back in the early nineties, we started experimenting with participatory methodologies – namely simulation debates on complex and controversial issues – in science education contexts (e.g. Camino and Calcagno, 1995). We shared the concerns of many educators around the world about the increasing separation of science teaching (and more generally, school life) from the lives of children and at a broader level, the alienation of young people and citizens from socio-environmental issues, which are affecting them both personally and as members of a community.

Not only the methods of teaching appeared to fail to motivate students but more importantly, it was felt that school science education as a whole was failing to prepare citizens to understand and develop competences for taking action in relation to complex issues.

While the civil society was confronted with arising issues of waste, resource depletion, risk and threats to human health and the environment associated with scientific and technological developments, school science education remained unchanged and unchallenged – transmitting disciplinary notions and contributing to reinforcing the image of a science that describes the world and strives for certainty.

Complex problems and educational responses

Socio-environmental problems are on the rise and becoming increasingly more urgent. Before millions of years of evolution, in the past 200 years human beings have acquired the capability of producing profound transformations on the natural systems. Steffen et al. (2007) refer to the current 100 years as the Anthropocene, "a geological epoch in which human beings and their societies have become a global geophysical force capable of creating global level changes in:

- the biological fabric of the Earth;
- the stocks and flows of major elements in the planetary machinery such as nitrogen, carbon, phosphorus, and silicon; and
- the energy balance at the Earth's surface" (p.614).

While humanity accounts for 0.5% of heterotrophic biomass on the Planet, it extracts about 32% of the total Net Primary Production (Imhoff et al., 2004). NPP—the net amount of solar energy converted to plant organic matter through photosynthesis—can be measured in units of elemental carbon and represents the primary food energy source for the world's ecosystems. Human appropriation of net primary productivity (HANPP), through the consumption of food, paper, wood and fiber, alters the composition of the atmosphere, levels of biodiversity, energy flows within food webs and the provision of important ecosystem services. Hence global environmental problems ranging from the micro to the macro-scale and on multiple levels - from organisms to communities arise from interconnected practices of food production and distribution, use of the soil and approaches to water services (Tilman et al., 2009).

Science is identified as a key player in current analyses of the environmental crisis but its role is ambiguous. In relation to large scale problems such as global climate change, usually dealt with by means of management of conspicuous amounts of data, scientific research grapples with estimates and the roles and responsibilities of human actions:

> *We can now say with some confidence that the increased rainfall intensity in the latter half of the twentieth century cannot be explained by our estimates of internal climate variability"* (Schiermeier, 2011).

The most rated academic journals embrace and augment the view of a science that will continue to bring solutions and innovation to overcome the current crisis (e.g. Alberts, 2008):

> *"Scientists and engineers […] share a belief that increased fundamental knowledge about the natural world will lead to human progress, because they see this happen in their own fields" (Alberts, 2008, p. 1435).*

Citizens, public administrations and policy-makers should thus confide in science in order to make private and public decisions, in full alignment with the well-known perspective described by Polanyi (1962) and Merton (1973)[1]. In a rebuttal to Alberts however, Guston et al (2009) underline the problematic features of the topic and its vast, social implications:

> *"Science and technology bring not only wonderful benefits, but also challenges and risks, from threats to personal and national security, to skewed distribution of wealth and social capital, to environmental and cultural degradation"(Guston et al. 2009, p. 582).*

Science and its technological applications constitute the essential know-how for undertaking increasingly extensive transformations of natural systems and social relationships, with unforeseen, unpredictable outcomes.

[1] Science … as open-minded, universalist, disinterested, and communal activity (Merton, 1973).

… And Education

Several authors started calling for approaches in science education aimed at teaching the nature of science and the history of science to highlight the role of culture and values in scientific developments (Matthews, 1994; Kolstø, 2001; Aikenhead, 2006). Other authors in the field of sociology of science and science studies called for a science of the citizens - or citizen science - for the necessity to involve citizens both as consumers and producers of science and technology (Irwin, 1995). From the field of global studies, Leach and Scoones (2007) argued for the acknowledgement of the global dimension of science and technology and of the inequities arising from their use and implementation, resource use and environmental impacts.

Within the sphere of science education, science educators started to pay a great deal of attention towards approaches aimed at preparing citizens to enter debates surrounding science ad technology. Earlier approaches developed from the field of Science, Technology and Society (i.e. Solomon, 1990; Pedretti, 1996) studies focussed on raising children's awareness of the interconnectedness between facts and values and to develop abilities to formulate decisions in democratic structures. More recently, drawing on the emphasis of the Public Understanding of Science (Millar, 2002) pedagogical implementations have focused more specifically on the acquisition of scientific language and skills that would enable students to produce logical, scientific arguments based on evidence (Lewis and Leach, 2006).

Conversely, in the parallel field of Science and Technology studies, a stream of voices has started to call for a redefinition of the role and purposes of science, supporting a type of science that is aware of its limitations and its ignorance (Jasanoff, 2007):

> *The great mystery of modernity is that we think of certainty as an attainable state. Uncertainty has become the threat to collective action, the disease that knowledge must cure (...) and that feeds the frenzy for new knowledge, much of it scientific* (p.33).

A positive approach to uncertainty recognises values and discussion as central elements to democracy (Sen, 2005) and it is open to the voices of other people, communities, languages and traditions in the search for a more equitable and sustainable scenario. Such change of epistemology leads to important changes of aims for education. The emphasis will shift from the acquisition of scientific knowledge and technical skills to developing relational and reflective competences to re-connect with the webs of biological, cultural and evolutionary relationships that sustain our life on the Planet.

Crisis of science and a science for sustainability

Our experiences with the use of participatory methods alongside other experiences of science and environmental education have led us in recent years to reflect more deeply on the nature of scientific knowledge and the implications of our own ideas of science, not only in the realms of teaching and learning but more generally in decision-making processes at a collective level and in the socio-economic relationships of our globalised world (Colucci-Gray et al., 2006).

We are now living in a historical time in which Western science has taken a dominant role and it has become 'global'. The network of international journals features contributions of scholars from all over the world that by means of the English language can communicate and collaborate in the production of new knowledge. Albeit its inevitable contradictions and revisions, modern science is considered both by the scientific community and the global society to be a 'universal' type of knowledge and superior to other forms of knowledge. Its relevant features are its characteristics of objectivity, generalisability, forecasting power and the ability to quantify and to model reality with increasing capacity. In other words, it is

perceived to be the most suitable and promising instrument for knowing the world and orienting future choices.

But like in most situations, the positive aspects are always accompanied by the negative ones: the dominance of the Western view of science (and the use of a single language) has suppressed – and in some cases it has swept away – modes of interpreting the world and of 'being in the world' which have been elaborated over thousands of years by other cultures and populations. Hence an important element for ensuring adaptability and resilience of a community (Maffi, 1998) - diversity - has gone missing, alongside the current biological instability of the Planet.

Critical voices

A variety of critical voices can now be more frequently heard coming from scholars from different disciplines who have expressed doubts about many aspects of modern Western science:

- about objectivity: any description of the world cannot exclude the choice of a language which - by its very nature - is the result of a particular culture and a particular historical time. Hence every language automatically conveys a worldview (e.g. Dodman, Camino and Barbiero, 2008; Camino and Dodman, 2009).
- about universality: contributions from post-colonial theory and gender studies in science have described the dominance of Western science as being the result of historical domination rather than pure and simple superiority of interpretive power. Such considerations have acquired further relevance nowadays in the light of the increasing disorder of the ecosystems caused by particular modes of production and usage of scientific knowledge.
- About its predictive power, which appear extremely limited as man's techno-scientific power continues to impact at increasingly deeper levels in the network of life, for example, we can think of the difficulties that exist in predicting the consequences of oceans' acidifications, the increasing turbulence in the atmosphere or the unknown effects of chemical compounds of different origin in the water systems. As it is increasingly the case with studies on climate change, the consequences of our actions appear to be known only a posterior (Schiermeier, 2011). Certain events are potentially known but they are not measured because they are considered to be irrelevant, expensive or unlikely e.g. the additive effects of pesticides in the aquifers; on bees populations, respiratory conditions... Some variables or processes that fall outside our mental schemata, do not acquire the status of variables (e.g. the biological components of the biosphere). And, finally, the complexity and interdependency of the natural systems are ignored (Capra, 2002).
- About neutrality: the growing gap between rich and poor, the inequities in resource distribution, the different levels of attention paid to the problems of restricted élites when compared to the problems of those who are deprived of essential means, are not simply deriving from bad governance but also to the choices and responsibilities of the scientific community.

While many people – by virtue of what is mainly a traditional idea of science - identify scientific and technological progress as the most secure way for resolving the global environmental crisis (e.g. Keith et al., 2010; Lovelock & Rapley, 2007), there are many others (Capra, 1996; Orr, 1992; Panikkar, 2005; Sachs, 2002; Sterling, 2002) who are asking whether the problem does not lie so much with the environment but with a particular way of thinking, the worldview that our society has elaborated and which is translated into political choices, environmental practices, individual behaviours and more specifically in the ways we produce and make use of scientific knowledge about the world as we know it. In this perspective, the

sustainability of human presence on the planet is dependent upon a radical shift of both culture (AA.VV, 2010) and epistemology (Gallopin et al., 2001), rather than higher levels of technological development (Lovbrand et al, 2009). As indicated by Latour (2007) we need to recognise our nature of 'Earthlings' and move away from the idea of modernization and emancipation from Nature to a concrete scenario of explicit recognition of our identity as beings dependent on Nature:

> *"Everything that earlier was merely "given" becomes "explicit". Air, water, land, all of those was present before in the background: now they are made explicit because we slowly come to realize that they might disappear —and we with them".*

And this includes a re-thinking of current views of science for "it is difficult to solve a problem if we do not recognise of being ourselves a part" (Sterling, 2002). In this perspective, knowledge can be acquired along with a reflective and critical attitude about how, why and when our own knowledge (meta-learning) and other ways of knowing (epistemological reflection about learning) have been developed.

Opening up towards dialogue

Scholars working within the field of 'sustainability science' (Kates et al., 2001; Clark, Crutzen & Schellnhuber, 2005) have called for the importance of a continuous dialogue amongst experts of different disciplines which allowed for integration of knowledge and the enrichment of perspectives. Another strand of the field of sustainability science and namely the post-normal science advanced by Funtowicz and Ravetz (1999) has stressed the need for the inclusion of not only the experts but all relevant stakeholders. Before the complex and controversial problems that we are continuously facing, a multiplicity of legitimate perspectives is needed. This mode of production recognises therefore that qualitative experiences, personal experiences of a place and familiarity with a situation or context are equally legitimate contributions and can have relevance alongside theoretical scientific knowledge when addressing open questions.

Other scholars (natural scientists as well as anthropologists, philosophers and educators) stress the need to question the traditional boundaries of academic science in order to enter into dialogue with different ways of seeing the world and create together new research paths. According to Ingold (2010) Western thought built upon the Aristotelian premises of form (morphé) and matter (hyle) – has progressively shifted towards a conceptualisation of the world as made prevalently of well distinct and separate objects while losing sight of the 'process' that is associated with all things. In recomposing our culture - a process of healing as indicated by Brian Goodwin (2007) - we can transform the boundaries of traditional scientific practice and progress towards a richer and more significant way of practicing science, by means of re-educating and re-equipping ourselves for a new life style, that includes cooperation with other cultures and with nature (Goodwin, 2007).

The thinking of the 'others'

Recently a special issue of the international journal 'Cultural Studies of Science Education' has been entirely devoted to reflecting on the relationships between scientific knowledge and indigenous knowledge. In the introduction, Aikenhed (2008) underlines the substantial difference that has characterised the two forms of knowledge for a long time: one is directed towards the description of how the world functions (episteme) and the other one is directed towards undertaking actions in the world (fronesis). Aikenhead also notes that fronesis does not simply mean 'practical thought' but 'practical wisdom': it is a way of knowing the world recognised by the majority of indigenous populations and it is prudent, necessary, moral and appropriate.

On the contrary, the equivalent of episteme is not recognised by indigenous populations. This concept presupposes that knowledge is entity that is separate from the subject: such an idea is alien to the indigenous perspective that recognises an intimate interconnection between the knowing subject and its ways of living (Aikenhead and Ogawa, 2007). By exploring with a new awareness of the conceptual limitations of every form of knowledge other forms of knowledge we can find the development of aspects that modern science had indeed neglected or suppressed (Berkes et al., 2000). For example, Aikenhead and Ogawa (2007) state the differences between aboriginal knowledge and western scientific knowledge at a number of different levels, involving methodologies, values and objectives. For example, the two forms of knowledge differ for their social goals, the wisdom-in-action aimed at survival, compared with individual scientific credibility, corporate profits or knowledge for its own sake. The two systems differ for their intellectual goals: co-existence with the mystery of nature by celebrating mystery through the maintenance of a host of relationships, compared with eradication of mystery by describing and explaining nature. They also differ for their association with human action: the intimate, subjective, moral and ethical wisdom stretching to account seven generations to come, compared with formally and objectively decontextualized knowledge. They also differ for a number of other aspects: the holistic perspective of aboriginal people with their accommodating, spiritual, intuitive wisdom compared with a collection of concepts, principles, and techniques that are mainly dualist, reductionist, anthropocentric, and that aspire to a universality goal. They even differ for their concept of time: circular for the aboriginal people and linear for western science.

Aikenhead and Ogawa (2007) argue that the two different knowledge systems while often presented in counter-opposition should enter some form of dialogue; yet this is different from accommodation of one perspective into the other (Stephens, 2000), but requires re-thinking of the idea of knowledge in context, that is not simply applied knowledge or traditional knowledge. Such expressions as indicated by Aikenehad fail to convey a new idea of knowledge, remaining encapsulated as they are within a Eurocentric framework that is continuously seeking to represent knowledge. Ways of thinking that diverge from the dominant view however can be found in modern times, both in the East and West. For example, in current modern India, a group of scholars has recently published a "Manifesto on Science and Technology" (KICS, 2009) in which it is pointed out - in the first instance – that in the new knowledge society, universities and research labs are no longer the sole producers of knowledge. The extraordinary development of means of communication that are accessible to the public obliges those places that are traditionally invested with the production and transmission of knowledge to enter into contact with other sources and ways of knowing, which are conveyed by a variety of new languages, symbols and images. After this premise, the authors introduce the concept of lokavidya a perspective on knowledge which recognises that the everyday life is a centre of knowledge production and not simply a place to apply knowledge built or constructed elsewhere. So for example, the knowledge held by a group of craftsmen working with wood, clay, metal and other materials used to produce objects of common use (clothes, tools, toys and so on…) is a dynamic form of knowledge, which is continuously changing and adapting in relation to the availability of raw resources, market forces and technical advancement. Hence it is both traditional and modern knowledge, practical and reflective because it has dynamically responded and adapted to new conditions (Gupta, 2000). Within this perspective, the authors of the manifesto found not only a means for achieving social sustainability but also a nonviolent approach to living in responsive adjustment to nature:

> *"By reworking the idea of the citizen as possessing a repertoire of knowledge,*
>
> *the secluded spaces into which modern knowledge has condemned the nomad, the tribal and the informal economy are opened up (…). To pluralise time is to pluralise the possibilities of life and living for cultures that do not follow modernity calendars. If time becomes unilinear and historical, the tribe might remain only as oral memory and the craft may only survive as an archive. The challenge here is mutual and reciprocal. The poetics of modern science lies in the multiplicity of time that it offers."(KICS, p. 13).*

Cultural diversity and sustainability

On the importance of biodiversity there is widespread agreement, both at the scientific and educational levels. Scientific research at an International level are involved in the promotion and conservation of biodiversity and the year 2010 was proclaimed by the UN the year of biodiversity.

But since the eighties, there were people who were proposing to include cultural diversity as a good to protect and respect: *"cultural capital includes the large variety of was in which societies interact with their environments: thus it includes cultural diversity"* (Gadgil, 1987). Some scholars have proposed to overcome the dichotomy between 'biological diversity' and cultural diversity' (which is particularly evident since the first documents produced by the Rio Convention in 1992) and to become aware that such separation is typical of Western thought, as observed by Bateson: "*the continuum of nature is constantly fragmented in a discontinuity of variables in the act of description*" (Bateson, cited by Berkes and Berkes, 2009).

In this perspective we find numerous scholars who are conscious of the risks and dangers of monocultures – also those ones of the mind (Shiva, 1998). A group of scholars (Pretty et al., 2009) has recently published a literature review on the topic summarising that:

- The diversity of life includes both biological diversity and cultural diversity which is expressed in beliefs, values, views of the world and cosmologies;
- Every natural environment provides the basis for the development of cultural processes, actions, beliefs and giving rise to a variety of language systems and modes of interactions which are intimately interconnected with their respective ecosystems.
- Many cultures and particularly those elaborated by indigenous and non-industrialised populations – have developed worldviews in which the human component is strictly interdependent with nature and they have put in place practices, norms and institutions aimed at maintaining a relationship that will allow for indefinite access to natural system services, source of life, food and well-being.
- The loss of cultural diversity which is happening by means of extinction of the language systems, cultures and knowledge will inevitably bring a loss of biodiversity which for thousands of years had been safeguarded by a complex set of practices based on local knowledge.

These scholars discuss how the mechanism of cultural assimilation that accompanies the domination of western science is depriving us of a wealth of approaches, experiences and ways of being that could instead enrich the western view. Without a dialogue between cultures we are deprived of that "other" who can allow us (as a process of mirroring) to acquire awareness of ourselves and that by means of dialogue could produce new forms of creativity, adaptation and resilience.

And science education?

To question the universality and dominance of modern western science is equivalent to re-discussing the whole of the epistemological and methodological implantation of science teaching (e.g. Aikenhead, 2008; 2010).

If we share the idea that a multiplicity of views and ways of interpreting the world is healthy and welcome then it is important to critically assess one's own role: for example, the implications of the hidden curriculum and the posture of the teacher in the class and more generally the school, with its structures, timetables, textbooks, assessment criteria and their responsibilities towards the exclusion and silencing of the knowledge systems elaborated by others.

In the light of these reflections, our task has been devoted to carrying out research on participatory learning contexts where attention was paid to both the learning process and its contextual conditions of involvement, self-expression, relationships and social climate. In this scenario, the role-plays alongside other methodologies of interdisciplinary and interactive teaching acquire new educational value. They become instruments through which students can reflect on the problematic features of disciplinary integration (for example, by uncovering the methodological basis underpinning the definition and meaning of particular concepts), the social and environmental aspects of controversial issues but also on the value and the necessity of other people's ideas (i.e. the non-experts, the citizens, people of different cultural extraction …) in order to elaborate ways of living which are both biologically and socially more sustainable.

From objective and objectifying science to a science of relationships

A possible itinerary (one of many…) that could help shaping one's own way of teaching science in a way that is a little different from the traditional approach could be that of always keeping in mind the *necessities of the other*.

- Other… is the colleague next door that is also involved in teaching my students in the realms of language, at or history. Interdisciplinary collaboration is crucial in helping students to re-compose the fragmented mosaic of knowledge. Even small-scale experiences may open the way to other initiatives that may become established over time.
- Other… are my students, each one with a different personality, history, talents, sometimes even language and culture. Each one of them has a treasure of experiences and knowledge that could – in appropriate conditions – be shared with peers and teacher within a educating community, operating under principles of socio-constructivism (e.g. Roth & Lee, 2004) and through the practice of Action-Research (Wicks & Rearson, 2009).
- Other… is my body, that I have been taught to approach as if it was separated from me, a shell, a passive instrument to the services of my will. Recent research in the neurosciences (e.g. Gallese, 2005; 2010) is showing the inseparability of motor and sensorial structures on the one hand and the environment on the other. Both the body and the environment interact in giving shape to the person in its entirety and ability to progressively adapt and respond to the world. Adolescents' bodies trapped at their desks cannot be doing a good service to cognitive structures and neither can they produce motivation for learning. A more dynamic management of the class and the use of forms of communication that include the body can promote and strengthen the embodied cognition.
- Other … is nature, from which we are progressively more separated. It is no longer a question of not knowing habitats and animal customs but it is the sense of not feeling at home in nature, not knowing how to move on foot on a mountain path or feeling lost in a woodland or not being able to perceive the difference between a material object (a 'product') and a living entity (a 'process' in continuous becoming). Getting out of the close boundaries of the class and the school to immerse ourselves together in the woods or climb up a mountain could (or maybe should?) be considered a necessary aspect of science education.
- Other… is my internal I, which is often silenced and left aside but with whom silence is the primary way of interaction. Experiences of active silence training proposed to children and young people have produced evidence of the importance of a period of silence to encounter oneself, restore attention and develop biophilia (Barbiero, 2007).

- Other… are those people that are different from me, carrying other cultures and other sciences and look at the world with different eyes and tell the world with words that I do not know. Those are the people that continuously make me aware that there are infinite possibilities for existence and for the realisation of a meaningful life and together they allow me to know myself (and transform) by means of comparison. The exchanges of correspondence between classes from different parts of the world can be source of extraordinary discoveries (Ferrero et al., 2005).

The need for all these others can be fulfilled by means of a relationship that is dialogue. Science can thus be re-thought as a modality of dialogical relationship between living things, people and with the natural systems. The premises of such change are both epistemological and methodological:

- not ONE science but many different ways of knowing and interpreting the natural systems, which in dialogue with one another (epistemological pluralism);
- involvement of all subjects (participatory democracy);
- recognition of language as a means for ordering space, relationships and our personal and reciprocal positions;
- recognition of the 'embodied nature' of all levels of life: from the cells, the body, the mind to the socio-ecosystems that evolve producing the holarchy of Gaia (Sahtouris, 2000).

And conflict?

Any dialogical relationship does not exclude conflict. Rather, every relationship contains an intrinsic element of conflict (Galtung, 1996). For such reason it is important to develop competences to develop non-destructive relationships: just like the mitochondria and the primordial cells, the male and female gametes allowing for the birth of a new individual, the microscopic guests living on and inside our bodies, the different forms of life populating the same ecosystem, the indigenous populations adapting to their natural environments.

However, acquiring positive attitudes towards conflict and more generally towards other people who may have different intentions, interests and goals is not something that occurs spontaneously. It is not simply a matter of tolerance for other views. It requires attentive listening to and respect for other people's views and this is a psychological and relational attitude which needs development and practice. According to the framework of sustainability science, in order to deal with the pressing problems facing us at the local and global levels we need to gather not only a variety of scientific information and knowledge but also a multiplicity of points of view, which are all equally legitimate. However, the legitimisation of the different voices is possible only if Western culture – and its most powerful instrument – techno-science – learn to step back from the ambition of supremacy and universality that have characterised its development so far. Already a few years ago, Chambers (1997) put this concept very clearly: in order to establish genuine dialogue between two participants, simply valuing the other is not sufficient…but one needs to revisit one's presence. With the words of Chambers:

> *The first step: empowerment. Putting the last first: altruism, generous behaviour towards poor, weak, isolated, vulnerable… but the first remains first.*
>
> *To go further: disempowerment… putting the first last: the uppers give up something, make themselves vulnerable… and gain effectiveness, liberation, fulfilment* (p. 138).

This perspective challenges established criteria of policy-making in science and the industry which are often based on an economics of efficiency and utilitarian ethics. If the last is to be first, or according to

Gandhi's Talisman – if the activity should ameliorate the condition of the weakest and the most needy individual – or Christ's pronouncement that any actions should be assessed with regard to the smallest, it would follow a change also at the cognitive level of democracy. This has important implications for matters such as energy and climate that have been traditionally associated with a non-cultural view of scientific knowledge. So for example, if science and technology are preoccupied with the large electricity systems, fuels and efficiency of production and distribution, a non-violent view would look at everybody's opportunities to exist and affirm one's life within the biophysical limits of the biosphere. Smil (2008) for example expressed this concept in numerical terms:

> *" at the beginning of the twenty-first century a purposeful society could guarantee a decent level of physical well-being and longevity, varied nutrition, basic educational opportunities and respect for individual freedom with annual TPES[2] of 50-70 GJ per capita (p. 387).*

So in a perspective of democratic pluralism based on equity, the analysis of energy flows and matter transformations is no longer and not exclusively pertaining to the realm of technocratic expertise but it is process of collective concern and engagement which is founded on basic needs, cooperation and multiple space-time perspectives (Colucci-Gray, 2009; Colucci-Gray et al., 2010).

Conclusions

Currently, with the many changes that have occurred in society, with the multiplication of environmental problems, the growth of power of techno-science and the rising of new barriers within society and amongst populations (Day et al., 2009), it is possible to give new value to participatory and interdisciplinary activities. The aim is that of re-composing the fractures, contextualise situations and allow young people to enter into direct forms of dialogue, by putting into relation the body with the emotions, images and languages – and so to give meaning to the many scientific concepts that by means of such activities can be acquired and integrated. In addition, we need to develop specific competences for nonviolent transformation of conflict (Galtung, 1996). Constructive transformation is at the heart of nonviolence and perhaps the most important acquisition of modern political culture for entering a sustainable phase of global socio-environmental change and… a change of climate.

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[2] TPES (Total Primary Energy Supply): in 003 the absolute range was from 1 GJ pro-capita for the poorest African countries to the 450 GJ pro-capita of Canada.

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